(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 686 481 A1

(12) # EUROPEAN PATENT APPLICATION published in accordance with Art. 158(3) EPC

(21) Application number: 95903950.4

(22) Date of filing: 22.12.94

(86) International application number: PCT/JP94/02205

(87) International publication number: WO 95/18010 (06.07.95 95/29)

(51) Int. Cl.6: B29C 67/06, B29C 35/16

(30) Priority: 24.12.93 JP 347882/93

(43) Date of publication of application: 13.12.95 Bulletin 95/50

(84) Designated Contracting States: AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE

(71) Applicant: K-Net Systems, Inc.
35-3, Hikarigaoka 1-chome
Komaki-shi,
Aichi 485 (JP)

(72) Inventor: KAWAGUCHI, Noboru
35-3, Hikarigaoka 1-chome
Komaki-shi
Aichi 485 (JP)

(74) Representative: Bannerman, David Gardner et al
Withers & Rogers
4 Dyer's Buildings
Holborn
London, EC1N 2JT (GB)

(54) ## LAMINATE MOLDING METHOD AND LAMINATE MOLDING APPARATUS

(57) A method of, and an apparatus for, applying a mold releasing agent to only necessary portions of a coagulation layer and capable of easily controlling an irradiation output of a laser beam. More particularly, it provides a method of, and an apparatus for, molding a laminate which can improve a work efficiency and can produce a laminate model having higher molding accuracy. To accomplish the objects, the present invention forms a slot groove (SG) in the coagulation layer (SL) by using a carbonic acid gas laser slot cutting machine (60) and divides a workpiece into a necessary region (SL1) for constituting a three-dimensional model and an unnecessary region not constituting a three-dimensional model. A laminate structure (LS) having a desired shape is obtained by repeating a slot forming step for forming the slot groove (SG), a mold releasing agent printing step for printing and applying the mold releasing agent (R) to a predetermined region (SL3) of the coagulation layer (SL), a coagulation agent applying step for applying the coagulation agent (S) to the uppermost surface of the laminate structure (LS) and a coagulation agent coagulating step for coagulating and curing the coagulant layer (SLL) applied and formed by a coagulation agent coagulating apparatus (50).

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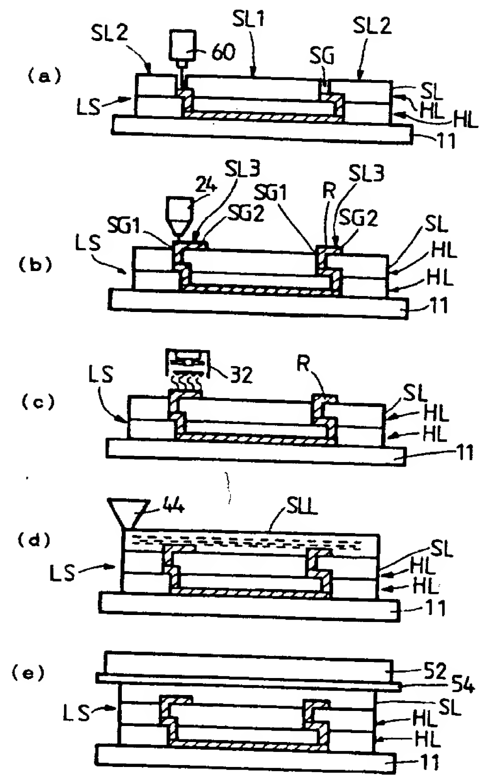
FIG. 3


(a)
SL2
60
SL1
SG
SL2
SL
HL
HL
LS
11
(b)
SL3
24
SG1
R
SL3
SG1
SG2
SG2
SL
LS
HL
HL
11
(c)
LS
32
R
SL
HL
HL
11
(d)
44
SLL
SL
HL
HL
LS
11
(e)
52
54
SL
LS
HL
HL
11

TECHNICAL FIELD

The present invention relates to a method for molding a laminate having a desired shape by laminating coagulating layers, and an apparatus used for the method, and particularly, to a laminate molding method and a laminate molding apparatus in which a releaser is printed by a press.

BACKGROUND ART

Conventionally, in development of new products, the fabrication of trial productions has been widely carried out. For example, in the automobile industry, in designing new model vehicles, first, a scale-down three-dimensional model is produced by way of trial, and design is studied, after which a three-dimensional model is again produced by way of trial to gradually determine the design of detailed portions. In this case, if a model is a three-dimensional model of a simple shape, preparation of an NC tape, management of knife edges and the like are necessary but the three-dimensional model can be comparatively easily formed using mechanical cutting means or the like. However, if a model is a three-dimensional model having a complicated shape, there exist problems in that it takes time for the molding by the mechanical cutting means and it is difficult to shape the detailed portions.

In view of the foregoing, a laminate molding method has been put to practical use as a method which, even in molding a simple three-dimensional model, requires no preparation of an NC tape, easy in the management of knife edges, and can shape even a three-dimensional model having a complicated shape in a short period of time. Such methods include, for example, a method for forming a mask pattern on a mask plate by an electrostatic toner, on the basis of data inputted into a computer in advance, placing the mask pattern on a resin layer coated with a photo-hardening resin to irradiate an ultraviolet light thereon, sufficiently exposing it, thereafter attracting an unhardened resin layer, filling with wax a clearance formed by removing the photo-hardening resin, thereafter cooling the wax, and repeatedly cutting the hardened resin layer and the wax to obtain a desirably-shaped three-dimensional model, and a method for forming a hardened layer by a photo-hardening resin and a coagulating agent.

In such a laminate molding method as described above, the photo-hardening resin is widely used as a molding material. Other methods include a method for obtaining a three-dimensional model having a desired shape by superposing a plurality of layers each formed from ordinary paper or the like while putting cuts therein, and a method for obtaining a three-dimensional model by pressing a powder of a coagulating agent into a hard lump to form a thin powder layer, applying a laser irradiation light thereto to thereby repeat sintering the portion to be irradiated to laminate the hardened layers, these methods being put to practical used.

According to these laminate molding methods, an inverted-warp model or the like can be easily formed, which has been heretofore difficult by mechanical cutting means or the like.
Further, a model provided with a precise construction can be formed.

However, in the method for forming a mask pattern, hardening a desired photo-hardening resin by an ultraviolet light having transmitted through the mask pattern, and filling with wax to obtain a three-dimensional model, there existed a problem in that the step of attracting a surplus photo-hardening resin is necessary, as a result of which noises resulting from the attraction are generated, and when the surplus photo-hardening resin is attracted, resins of finely shaped portions are absorbed or the surplus resins remained in the fine portions, failing to obtain a model having a high precision, particularly a model whose contour portion is high in precision.

Further, in this method, the cutting is carried out in order that after the wax has been filled, the layers comprising the photo-hardening resin and the wax are arranged into a predetermined thickness in preparation for coating of a successive layer. However, there exists a problem in that when the surface of the photo-hardening resin once hardened is cut, the surface activity of the photo-hardening resin lowers, and even if an unhardened photo-hardening resin is coated thereon, the adhesive performance of upper and lower layers becomes worsened. There is a further problem in that energy consumption as the whole apparatus is large.

Furthermore, in the method for forming a thin powder layer and irradiating a laser beam thereon to sinter the powder layer into a desired shape, it is necessary to irradiate the laser beam over the wide range to sinter the powder, but there exists a problem in that the depthwise sintering characteristic is not stabilized, making it difficult to obtain a firmly bonded model. This generally results from the fact that proper control of irradiation output of the laser beam is difficult, and control of irradiation output of the laser beam in a very narrow range is demanded in order to sinter only the thin powder layer as intended.

Moreover, in the method for coating and coagulating a coagulating agent, after which a part thereof is shaved off by irradiating a laser beam, and filling it with a photo-hardening resin which functions as a releaser, there occurs a problem in that filling of the photo-hardening resin in only the

necessary portion is not realized, and therefore, it is necessary to shave off many portions to fill the many portions with the photo-hardening resin, resulting in a poor working efficiency and a high cost.

Further, there was a problem in that these laminate molding apparatuses need be applied with a temperature management, dust measures and the like, and the installation site is limited because of generation of vibrations and noises.

The present invention has been accomplished in order to solve the aforementioned problems. An object of the invention is to provide a laminate molding method and apparatus capable of coating a releaser on only necessary portions of a coagulating layer and capable of easily controlling an irradiation output of a laser beam. Another object of the invention is to provide a laminate molding method and apparatus of enhancing a working efficiency and capable of obtaining a laminate model which is higher in molding precision.

DISCLOSURE OF THE INVENTION

For achieving the aforementioned objects, the present invention provides a laminate molding method for laminating hardening layers composed of a coagulating agent and a releaser to thereby obtain a laminate having a desired shape, the method comprising: a first step of forming a slot groove in a coagulating layer constituting a surface of said laminated hardening layer to divide the coagulating layer into a necessary region constituting the laminate having a desired shape and an unnecessary region not constituting the laminate having a desired shape; a second step of printing a releaser on a predetermined region of a coagulating layer constituting the surface of said hardening layer or a predetermined region of a coagulating agent sheet constituting a new coagulating layer; a third step of forming a new non-coagulated state coagulating agent layer on said coagulating layer on which the releaser is printed or on said hardening layer; and a fourth step of coagulating said coagulating agent layer to form a new hardening layer.

In the third step, it is preferable that a non-coagulated coagulating agent is applied in a predetermined thickness to the surface of the coagulating layer on which the releaser is printed to form a semi-coagulated coagulating agent layer. In this case, the releasing agent used in the second step is preferably a photo-hardening resin material, and the coagulating agent used in the third step is preferably a coagulating agent in which a polyvinyl alcohol and a co-compound are added to urea. Further, in the third step, a coagulating sheet may be placed on the coagulating layer on which a releaser is printed to melt the coagulating sheet, thereby forming a non-coagulated coagulating agent layer, and a coagulating agent sheet on which a releaser is printed may be cut out into a predetermined size, and the thus cut-out coagulating agent sheet may be molten to thereby form a non-coagulated coagulating agent layer. Further, preferably, the releaser used in the second step is a slurry-like ceramic having a high heat resistance, and the coagulating agent used in the third step is metal to be flame-sprayed from a metal flame-spraying apparatus.

In this case, as the coagulating agent sheet, there can be used a coated paper in which a coagulating agent is applied to paper which is a fibrous sheet. The thickness of the coated paper is 0.1 to 0.2 mm, and the coating thickness of the coagulating agent may be 20 to 50 μm or so. In case of using one in which a coagulating agent is applied to the paper, this is allowed to pass through a heat roller or the like in advance, whereby the coagulating agent on the coated paper is molten, in which it is placed on the coagulating layer on which the releaser is printed to coagulate it so as to form a new hardening layer. By doing so, there is produced the merit in that the production efficiency is enhanced and the productivity is improved as compared with the method in which even if the coagulating agent sheet is placed on the coagulating layer on which the releaser is printed and then heated and molten, after which it is coagulated.

Further, in the third step, if the releaser printed on the coagulating layer is not solidified, when the coagulating agent sheet is placed thereon, the releaser is sometimes spread laterally between the coagulating agent sheet and the coagulating layer. In case of using one in which a coagulating agent is applied to the coated paper, since the coated paper itself is fibrous, the releaser may permeate the coated paper but is not spread laterally. Accordingly, in the step in which the step returns to the first step later in which a slot groove is formed in the coagulating layer on the basis of a section vector data in which a three-dimensional model is sent to form a contour, one which is high in adhesive strength of the contour portion and small in shape is finished. Moreover, in that case, even if the releaser printed on the coagulating layer in the third step is not hardened, one in which the coagulating agent is applied to the coated paper can be heated and molten and then superposed (placed), and therefore, the productivity can be further enhanced.

Furthermore, the provision of a coated paper which is cheaper than a 100% coagulating agent sheet as a constituent element of a laminate shaped article can provide more inexpensive shaped article, producing the economical advan-

tage.

The second step in the above-described laminate molding method is preferably the step in which a releaser is printed on a coagulating layer corresponding to a necessary region, an unnecessary region and an exclusive logic sum region of a slot groove formed in each of upper and lower hardening layers. The fourth step is preferably the step in which a non-coagulated coagulating layer is pressed against a temperature-regulating plate through a film having a releasing property to thereby form a hardening layer. Further, the first step is preferable to irradiate a laser beam to form a cut, and in this case, preferably, a slot is formed at a predetermined angle of inclination within a vertical plane with respect to the slot forming direction. Further, in the first step, plural colors of releasers can be used so that colors as desired can be emitted in the regions as desired.

If the slurry-like ceramic is used as the releaser, and the metal flame sprayed from the metal flame spraying device is used as the coagulating agent, as the fourth step, even if the temperature regulating plate is not subjected to the plane molding, the coagulating agent is coagulated at the time of coating in the subsequent third step merely by cooling it by a blower.

Further, in the third step in which the coagulating agent layer is formed on the coagulating layer on which the releaser is printed, if one in which a coagulating agent is applied to paper is used, since the coated paper itself has heat retaining properties, the operations of the first, second and third steps are repeated several times in order, after which as the fourth step, natural air cooling is effected to terminate the operation, and then, a heater is turned off and cooling is effected by only the blower. Furthermore, in this case, if the heat retaining properties of the coated paper disposed in the laminate is taken into consideration, the warp caused by the lamination can be relieved or avoided even if the plane molding at the time of cooling using the aforementioned temperature regulating plate is not carried out.

Further, the present invention provides a laminate molding apparatus for laminating hardening layers composed of a coagulating agent and a releaser to thereby shape a laminate having a desired shape, the apparatus comprising: slot forming means for forming a slot groove in a coagulating layer constituting a surface of the laminated hardening layer to divide the coagulating layer into a necessary region constituting the laminate having a desired shape and an unnecessary region not constituting the laminate having a desired shape; releaser print means for printing a releaser on a predetermined region of a coagulating layer constituting the surface of the hardening layer or a predetermined region of a coagulating agent sheet constituting a new coagulating layer; coagulating agent layer forming means for forming a new non-coagulated coagulating agent layer on the coagulating layer on which the releaser is printed or on the hardening layer; and coagulating agent layer coagulating means for coagulating the coagulating agent layer to form a new hardening layer.

The coagulating agent layer forming means forms a non-coagulated coagulating agent layer by applying a non-coagulated coagulating agent onto the surface of the laminate on which a plurality of hardening layers are laminated and formed to a predetermined thickness and is preferably a spray applicator for spraying a non-coagulated coagulating agent on the surface of the laminate on which a plurality of hardening layers are laminated and formed to a predetermined thickness or a gravure coater capable of coating a thin film having a high precision. The coagulating agent layer forming means may be constituted of coagulating agent sheet placing means for placing a coagulating agent sheet on the coagulating layer on which a releaser is printed, and coagulating agent layer melting means for melting the coagulating agent sheet to form a non-coagulated coagulating agent layer, or may be constituted of coagulating agent sheet placing means for placing the coagulating agent sheet on which a releaser is printed on the hardening layer, coagulating agent sheet cut-out means for cutting out the coagulating agent sheet into a predetermined size, and coagulating agent layer melting means for melting the coagulating agent sheet to thereby form a non-coagulated coagulating agent layer.

In the aforementioned laminate molding apparatus, the slot forming means is preferably a laser beam irradiation machine and a mechanical cutter, and the releaser printing means is preferably an ink jet type printer or an electrostatic transfer type printer.

As the aforementioned releaser printing means, when a pen plotter is used, a tool change between a pen and a cutter can be easily made, in relation to the case where a cutter plotter is used as the slot forming means, thus providing the convenience that an XY direction positioner can be commonly used. Further, if a laser irradiation device is used as the slot forming means, a tool change between a laser irradiation head and a pen can be made. By doing so, such a convenience is produced that a control device for the XY direction positioner can be commonly used between a pen and a laser.

The laminate molding method according to the present invention having the above-described construction is the method for laminating hardening layers composed of a coagulating agent and a releaser to thereby obtain a desirably shaped lami-

nate. The first step is provided so that a slot groove is formed in a coagulating layer constituting the surface of a laminated hardening layer, and the coagulating layer is divided by the slot groove into a necessary region constituting a desirably shaped laminate and an unnecessary region not constituting a desirably shaped laminate to secure releasability with respect to a necessary region of successive layer formed in the subsequent step, an unnecessary region of an already formed layer and a slot groove. The releasability with respect to a necessary region, an unnecessary region and a slot groove can be secured to easily obtain a laminate having a desired shape. The slot groove can be easily formed when it is formed using a laser beam. Further, if a slot groove is formed at a predetermined angle of inclination within a vertical plane with respect to the slot forming direction, a desirably shaped portion of a laminate finally obtained can be easily separated from a surplus portion.

Subsequently, in the second step, a releaser is printed on a predetermined region of a coagulating layer constituting a surface of a hardening layer or on a predetermined region of a coagulating agent sheet constituting a new coagulating layer. This releaser is printed on a coagulating layer corresponding to an exclusive logic sum region between a necessary region, an unnecessary region and a slot groove formed on a hardening layer formed this time, and a necessary region, an unnecessary region and a slot groove formed on a hardening layer formed next time. That is, the second step is provided so that the releaser is printed from the slot groove formed previously to the slot groove formed next time to prevent the slot groove from being blocked by the coagulating agent, a desirably shaped portion of a laminate finally obtained is easily separated from a surplus portion. At this time, if plural colors of releasers are used, desired colors can be emitted in desired regions to improve the discrimination.

Further, in the third step, a new non-coagulated coagulating agent layer is formed on a coagulating layer having a releaser printed thereon or on a hardening layer. The third step is carried out so that a non-coagulated coagulating agent is applied to the surface of a coagulating layer having a releaser printed thereon to a predetermined thickness. If the coagulating agent used herein is one in which polyvinyl alcohol and a co-compound are added to urea, releasability from the releaser formed of a photo-hardening resin material previously printed is excellent.

Further, in the third step, a coagulating agent sheet is placed on a coagulating layer having a releaser printed thereon, and the coagulating agent sheet is molten to form a coagulating agent layer in a non-coagulated state. Further, a coagulating agent sheet having a releaser printed thereon is cut out into a predetermined size, and the cut-out coagulating agent sheet is molten to form a coagulating agent layer in a non-coagulated state. By doing so, the coagulating agent can be easily handled.

When the coagulating agent layer in the non-coagulated state is formed, the fourth step is carried out for coagulating the coagulating agent layer to form a new hardening layer including a releaser. The fourth step is carried out by pressing the coagulating layer in the non-coagulated state against the temperature regulating plate through a film which is high in releasability. The film having a high releasability is interposed between the coagulating agent layer and a flat plate, and the coagulating agent layer is pressed against the flat plate. Therefore, it is possible to easily form a coagulating layer having a uniform thickness, and obtain an excellent peelability.

The first to fourth steps are repeated, whereby many hardening layers are superposed and laminated to obtain a laminate having a desired shape.

The laminate molding apparatus provided with the above-described construction according to the present invention is the apparatus for laminating a plurality of hardening layers composed of a coagulating agent and a releaser, to thereby shape a laminate having a desired shape. A slot groove is formed in a coagulating layer constituting a surface of a hardening layer by slot forming means, and the coagulating layer is divided by the slot groove into a necessary region constituting a desirably shaped laminate and an unnecessary region not constituting a desirably shaped laminate.

The slot forming means is controlled on the basis of laminate section data of a laminate having a desired shape, and a contour having a laminate section is formed by the slot groove. If a laser beam irradiation machine is used as the slot forming means, the slot groove can be easily formed. If a mechanical cutter is used, a slot depth having a high precision can be formed, and a slot width can be narrowed.

The releaser printing means is provided to print a releaser on a predetermined region of a coagulating layer constituting a surface of a hardening layer or a predetermined region of a coagulating agent sheet forming a new coagulating layer. The releaser printed by the releaser printing means is printed on a coagulating layer corresponding to an exclusive logic sum region between a necessary region, an unnecessary region and a slot groove formed on a hardening layer formed this time, and a necessary region, an unnecessary region and a slot groove formed on a hardening layer formed next time.

That is, in superposing the laminate sections, the slot groove is filled up, a desirably shaped portion and a surplus portion of a laminate cannot be separated. But according to this configuration, the separation therebetween can be easily made avoiding the aforementioned state. Preferable releaser printing means used herein include an ink jet type printer or an electrostatic transfer type printer. By using these printers, a releaser can be printed accurately on only the predetermined region.

The coagulating agent layer forming means is provided to form a new coagulating agent layer in a non-coagulated state on a coagulating layer having a releaser printed thereon or on a hardening layer. A coagulating agent layer is formed by coating a non-coagulated coagulating agent on the surface of a laminate or by spraying a non-coagulated coagulating agent to a predetermined thickness using a spray applicator. Alternatively, it is possible that a coagulating agent sheet is placed on a coagulating layer having a releaser printed thereon by coagulating agent placing means, the coagulating agent sheet is molten by coagulating agent layer melting means to form a coagulating agent layer in a non-coagulated state. It is also possible that a coagulating agent sheet is placed on a coagulating layer having a releaser printed thereon by coagulating agent placing means, the coagulating agent sheet is cut out into a predetermined size by coagulating agent sheet cut-out means, and the coagulating agent sheet is molten by coagulating agent layer melting means to form a coagulating agent layer in a non-coagulated state.

As already described, if a slurry-like ceramic is used as a releaser, and metal flame-sprayed from a metal flame-spraying device is used as a coagulating agent, metal in a non-coagulated state is flame-sprayed on a coagulating layer having a releaser printed thereon or on a coagulating layer by the metal flame-spraying device to form a new coagulated-state coagulating agent layer.

Further, as already described, if a material in which a coagulating agent is applied to a paper as a fibrous sheet is used as a coagulating sheet, this is allowed to pass through a heat roller or the like in advance, whereby a material in which a coagulating agent is molten on a coated paper is placed on a coagulating layer having a releaser printed thereon, and this is coagulated to form a new hardening layer.

The coagulating agent layer coagulating means is provided to coagulate a coagulating agent layer in a non-coagulated state to form a new hardening layer including a releaser, whereby a single hardening layer is formed, and such hardening layers are stacked to thereby obtain a laminate having a desired shape.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory view showing the entire structure of a three-dimensional model molding system according to the present invention;

Fig. 2 is an explanatory view schematically showing the structure of a slot cutting machine;

Figs. 3(a) to 3(e) are sectional views of the steps schematically showing processes in the respective steps of a laminate molding method in a first embodiment;

Figs. 4(a) to 4(e) are sectional views of the steps schematically showing processes in the respective steps of a laminate molding method in a second embodiment;

Figs. 5(a) to 5(d) are sectional views of the steps schematically showing processes in the respective steps of a laminate molding method in a third embodiment; and

Figs. 6(a) to 6(d) are sectional views of the steps schematically showing processes in the respective steps of a laminate molding method in a fourth embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

Detailed embodiments of the present invention will be described hereinafter with reference to the drawings.

First, the entire structure of a three-dimensional molding system in the present embodiment will be described with reference to Fig. 1. Fig. 1 is an explanatory view showing the entire structure of a three-dimensional model molding system MS.

The three-dimensional model molding system MS is composed of a graphic work station 200 and a molding apparatus 300, where the graphic work station 200 prepares section vector data representative of a sectional shape of a three-dimensional model on the basis of shape data of the three-dimensional model, to supply the prepared section vector data to the molding apparatus 300. The method for preparing section vector data representative of a sectional shape of a three-dimensional model from CAD (Computer Augmented Design) data is known in the field of CAD, which is described in detail in Japanese Patent Laid-Open No. Sho 63-72526 and Japanese Patent Laid-Open No. Hei 2-78531, description of which is therefore omitted.

The molding apparatus 300 is composed of a laminate placing unit 10 for placing a laminate structure LS to arrange it at a predetermined position, a slot cutting machine 60 for forming a slot groove SG in a coagulating layer SL to divide the coagulating layer SL into a necessary region SL1 constituting a three-dimensional model and an un-

necessary region SL2 not constituting a three-dimensional model, a releaser printing device 20 for printing a releaser R on a predetermined region SL3 of the coagulating layer SL (an exclusive logic sum region of a necessary region SL1 formed on a hardening layer formed this time, an unnecessary region SL2, and a slot groove SG, and a necessary region SL1 formed on a hardening layer formed next time, an unnecessary region SL2 and a slot groove SG), a releaser hardening device 30 for hardening a printed releaser R, a coagulating agent coating device 40 for coating a coagulating agent S on the surface of a laminate structure LS, a coagulating agent layer coagulating device 50 for coagulating the coated coagulating agent S, and a control device 70 for controlling the aforementioned constituent devices.

The laminate placing unit 10 is provided with a table 11 for placing a laminate structure LS being shaped, a motor 12 for moving the table 11 in a vertical direction in order to press the laminate structure LS against the coagulating agent layer coagulating device 50 or in order to lower a position of the surface of the laminate structure LS by a height laminated every time a new hardening layer is laminated on the laminate structure LS, and a table position detector (not shown) for detecting a vertical absolute position of the table 11.

The coagulating agent coating device 40 is the apparatus for coating a coagulating agent S on the surface (the uppermost surface) of a new hardening layer HL laminated on the laminate structure LS. This apparatus is composed of a melt tank 42 in which a solid coagulating agent S is molten by a heater 46, and the liquid coagulating agent S is stored, and a coating head 44 having an elongated coating port which extends over the width in a direction of X (a direction vertical to paper surface) of the laminate structure LS in order to coat the coagulating agent S on the uppermost surface of the laminate structure LS, being engaged with a Y rail 16 extending in a direction of Y and being driven by a motor, not shown, whereby the coating head is moved in a direction of Y.

The coagulating agent layer coagulating device 50 is the apparatus for cooling the coagulating agent S applied to the uppermost surface of the laminate structure LS to completely harden it and holding the coagulating layer SL at a constant temperature. This apparatus is composed of a temperature regulating plate 52 which is controlled in temperature by a temperature detector, not shown, and a temperature controller, and a release film 54 fixedly mounted to two sides of the temperature regulating plate 52 so that a central portion thereof is suspended.

The slot cutting machine 60 will now be described with reference to Fig. 2. Fig. 2 is an explanatory view schematically showing the structure of the slot cutting machine 60.

The slot cutting machine 60 is composed of a carbon dioxide gas laser 61 which is controlled by a pulse width controller, not shown, and whose pulse width is adjusted so that energy per unit step of a light spot in the surface of the coagulating layer SL becomes equal, a beam expander 62 for enlarging a beam diameter of a laser beam, a group of reflecting mirrors 63, 64 and 65, 66 for changing the course of the laser beam, a focusing portion 67 for determining a focal point of the laser beam, an oscillating portion 68 for varying an irradiation angle of the laser beam, and a movable bed 69. On the movable bed 69 which is driven by a first motor, not shown, to move in a direction of Y are installed the aforementioned group of reflecting mirrors 63, 64 and 65, 66, the focusing portion 67 and the oscillating portion 68. Further, the group of reflecting mirrors 63, 64 and 65, 66, the focusing portion 67 and the oscillating portion 68 are moved in a direction of X by a second motor, not shown.

The releaser printing device 20 is composed of a tank 22 for storing the releaser R, and a printing head 24 which is engaged with an X rail 18 extending in a direction of X and driven by the first motor, not shown, and moved in a direction of X to print the releaser R on a predetermined region of the coagulating layer SL and a slot groove SG. The printing head 24 used herein is an ink jet type printing head, whose construction and function are known, description of which is therefore omitted. Further, the X-rail 18 is engaged with the Y-rail 16 extending in a direction of X, which is driven by the second motor, not shown, and moved in a direction of Y.

The releaser hardening device 30 is the apparatus for drying and hardening the releaser R printed on the predetermined region SL3 of the coagulating layer SL and the slot groove SG, the apparatus being composed of a hot air blowing port 32 which is engaged with the Y-rail 26 extending in a direction of Y and driven by a motor, not shown, and moved in a direction of Y. Dry hot air is blown out of the hot air blowing port 32 toward the releaser R, whereby the releaser R is dried and hardened.

The control device 70 is the apparatus for controlling the devices such as the slot cutting machine 60, the releaser printing device 20 and the like constituting the molding apparatus 300 on the basis of the section vector data of the three-dimensional model supplied from the graphic work station 200, to obtain a three-dimensional model having a desired shape. The section vector data representative of a section of a desired three-dimensional model according to a present laminated position of the laminate structure LS are sequentially supplied

to the control device 70.

Next, the laminate molding method for molding the laminate structure LS will be described using the aforementioned devices with reference to Fig. 3 while explaining the function of various devices. Figs. 3(a) to 3(e) are sectional views of the steps schematically showing processes in the respective steps of a laminate molding method. In the following description, it is assumed that a plurality of hardening layers HL have been already laminated.

The laminate molding method comprises the slot forming step for forming a slot groove SG in a coagulating layer SL and dividing the coagulating layer SL into a necessary region SL1 constituting a three-dimensional model and an unnecessary region SL2 not constituting a three-dimensional model, the releaser coating step for coating a releaser R on a predetermined region SL3 of the coagulating layer SL, the coagulating agent coating step for coating the coagulating agent S on the uppermost surface of a laminate structure LS, and the coagulating agent coagulating step for coagulating and hardening the coated coagulating agent S to form the coagulating layer SL.

First, shape data of a desirably shaped three-dimensional model are inputted into the graphic station 200 to prepare section vector data. This prepared section vector data are transmitted to the molding apparatus 300, and the slot forming step is first executed on the basis of the section vector data transmitted. This slot forming step is carried out as shown in Fig. 3(a), and the slot cutting machine 60 provided with a carbon dioxide gas laser is used.

The carbon dioxide gas laser type slot cutting machine is engaged with the Y-rail 16 on the basis of the section vector data transmitted from the graphic work station 200, the movable bed 69 provided with the group of reflecting mirrors 63, 64 and 65, 66, a focusing portion 67, and the oscillating portion 68 is driven and moved in a direction of Y by the first motor, not shown, and parts of the group of reflecting mirrors 63, 64 and 65, 66, the focusing portion 67, and the oscillating portion 68 are moved in a direction of Z by the second motor, not shown, whereby a sectional contour of a three-dimensional model is formed on the surface of the coagulating layer SL by the slot groove SG.

This slot groove SG is formed by vaporizing (sublimating) and varnishing the coagulating agent S which is present at a location, where a laser beam outputted from the carbon dioxide gas laser 61 is irradiated. The laser beam outputted from the carbon dioxide gas laser 61 is enlarged in beam diameter by the beam expander 62 and changed in course by the group of reflecting mirrors 63, 64 and 65, 66 and formed in focal point by the focusing portion 67. Further, the slot cutting machine 60 used herein is provided with the oscillating portion 68 so that an irradiation angle of the laser beam can be varied within the X-Z plane to thereby form the slot groove SG having a draft angle.

The carbon dioxide gas laser 61 is adjusted in output so that the depth of the slot groove SG formed is at least more than a thickness of the coagulating layer LS. According to the prior art, in this case, it has been necessary to perform the precise laser output control in order to considerably shave off the coagulating layer SL to form a recess portion, or in order to melt and bond powders of the coagulating agent S. However, in the present embodiment, the slot groove SG is merely formed in the coagulating layer LS, and therefore, the precise output control need not be performed and the carbon dioxide gas laser 61 can be easily handled.

At this time, preferably, the releaser R printed on the predetermined region SL3 of the coagulating layer LS having a temperature higher than a vaporization (sublimation) temperature of the coagulating agent S is used to prevent the releaser R from being varnished. If the releaser R having a vaporization temperature higher than that of the coagulating agent S is used, the output control of the carbon dioxide gas of the carbon dioxide gas laser 61 is further facilitated.

In this way, When the slot groove SG is formed in the coagulating layer SL, the coagulating layer SL is divided into the necessary region SL1 constituting a desirably shaped three-dimensional model and the unnecessary region SL1 not constituting a three-dimensional model. The predetermined region SL3 of the surface of the coagulating layer SL divided into a plurality of regions is subjected to the releaser printing step for printing the releaser R in order to prevent the slot groove SG from being blocked by the coagulating agent coating step carried out next time and in order to enhance the separation characteristics of the laminate structure LS. This releaser printing step is carried out by the releaser printing device 20 as shown in Fig. 3(b).

In the present embodiment, as the releaser printing device 20, an ink jet type printer is used. The releaser R stored in the releaser tank 22 is supplied to the ink jet type printing head through the supply pipe 21. The printing head 24 is driven by the first motor, not shown, and guided to the X-rail 18, and then moved in the direction of X, to effect the printing in the range from the slot groove SG1 formed this time to the slot groove SG2 formed next time.

In this manner, when the printing head 24 is moved in the direction of X, it is then driven by the second motor, not shown, guided by the Y-rail 16, moved in the direction of Y and again moved in the

direction of X. This cycle of operation is repeated to complete the printing of the releaser R onto a necessary spot of the coagulating layer SL. It is to be noted that if coating (printing) takes place so as to prevent the next coagulating agent S from entering the slot groove SG, the coagulating agent S need not always be filled in the slot groove SG.

In this way, the releaser R is printed by the printing device, whereby the releaser R can be coated (printed) on only the desired position to shorten the time for coating the releaser R and shorten the time for drying it. Particularly, since the ink jet type printer is used, the printing time can be considerably shortened. Further, since the releaser R is coated (printed) in very thin using the printing device, even if laminates are stacked, no thickness effect is produced.

The releaser R used herein is preferably higher in viscosity than a urea mixture in the molten state. This is because of the fact that when the next releaser S is applied to the portion on which the releaser R is printed, the releaser R is prevented from being removed. A preferable example of the releaser R is KF96 manufactured by Shin-Etsu Chemical Co., Ltd. which is silicone oil. The viscosity of the releaser R is 100,000 cs at its maximum.

Other examples of the used releaser R include a wax releaser, and various inks which are mixtures of a mineral fine power and a solvent. If various inks are used as a releaser, the adhesiveness to the coagulating layer SL increases, and a coagulating agent S having a high viscosity can be used. Further, a photo-hardening resin can be also used. For example, Benefix PC made of Ader, which is a photo-hardening adhesive, may be used. Use of the photo-hardening resin leads to the merit that the hardening time is short and the solvent is not vaporized. In a second embodiment described later, the case will be described in which a photo-hardening resin is used as a releaser R.

The releaser R thus printed on the predetermined region SL3 is dried and hardened by the releaser hardening device 30 as shown in Fig. 3(c). The releaser hardening device 30 is driven by the motor, not shown, and blows out dry and hot air from the hot air blowing port 32 while moving in the direction of Y to dry and harden the releaser R printed on the predetermined region SL3.

When the releaser R is printed and dried, the coagulating agent coating step is carried out using the coagulating agent coating device 40, as shown in Fig. 3(d). When the coagulating agent S is charged into the melting tank 42, the coagulating agent S becomes melted by a heater 40 encircling the melting tank 42. The melted coagulating agent S is supplied to the coating head 44 through the supply pipe 43 and applied to the surface (the uppermost surface) of a new hardening layer HL laminated on the laminate through a coating port extending in an elongated manner over the width in the direction of X of the laminate structure LS.

Since the coagulating agent coating device 40 provided with the coating head 44 is driven by the motor, not shown, and thereby moved in the direction of Y along the Y-rail 16, when the coagulating agent S is continuously supplied, whereby the coagulating agent S is evenly coated over the Y direction of the laminate structure LS to form a coagulating layer SLL. The thickness of the coagulating layer SLL formed at that time is preferably about 25 μm to about 250 μm.

In the coagulating agent S used herein, a urea mixture described in Japanese Patent Laid-Open No. Hei 2-55638 is used, which is a urea mixture added with polyvinyl alcohol and a co-compound. The co-compound is a compound which is co-bonded with urea at a low temperature to greatly lower a melting point or a coagulating point of a co-material, examples of which are benzoic acid, benzene sulfonic acid, benzene sulfonic acid, benzoyl chloride, glycine, naphthalene, glutaric acid, etc. The urea mixture has a melting point of approximately 120 °C, which is higher than a room temperature, so that the mixture is heated by the heater 46 provided around the melting tank 42 to maintain it in a melting state. It is to be noted that the producing method and properties of the urea mixture are described in detail in Japanese Patent Laid-Open No. Hei 2-55638, description of which is therefore omitted.

Other coagulating agents S that may be used include thermoplastic engineering plastics heated and melted (polycarbonate, an ABS resin, polyethylene, etc.), and waxes heated and melted (paraffin, polyethylene glycol, etc.). If the engineering plastics are used, a three-dimensional model formed of the engineering plastics can be obtained by removing the releaser R and can be used without modification, and in addition, a model can be shaped by selecting plastics according to the use of a final model. Further, if a mixture in which polyvinyl alcohol and a co-compound are added to urea or wax are used, a model for precise casting can be provided.

In this way, when a new coagulating agent layer SLL is formed, the coagulating agent coagulating step for coagulating the coagulating agent layer SLL using the coagulating agent layer coagulating device 50 mentioned previously is carried out, as shown in Fig. 3(e).

Since the coagulating layer coagulating device 50 is fixed, the table 11 for the laminate placing unit 10 is driven by the motor 12 and moved upward in order that the coagulating agent layer SLL applied to the surface of the laminate structure LS placed on the table 11 of the laminate placing

unit 10 is pressed against the temperature regulating plate 52 of the coagulating agent layer coagulating device 50. At this time, the moving amount of the table 11 is detected by the table position detector for detecting the vertical absolute position of the table 11, not shown, so that the coagulating layer SLL is formed into the coagulating layer SL having a predetermined thickness, and the detected data is used for the selection of the section vector data to be transmitted next.

The coagulating agent layer SLL is pressed against the temperature regulating plate 52 through the release film 54 fixedly mounted on the side of the temperature regulating plate 52. The temperature regulating plate 52 is adjusted in temperature to a constant value by a temperature detector and the temperature regulating plate 52 is adjusted in temperature to a constant value by a temperature detector and a temperature regulating portion, not shown, and is a smooth flat plate. Therefore, the pressed coagulating layer SLL is quickly coagulated to form a coagulating layer SL having a predetermined thickness provided with a smooth surface. The coagulating agent layer SLL is naturally cooled before being pressed against the temperature regulating plate 52 and is in a coagulated and hardened state to some extent. However, the coagulating agent layer SLL is pressed against the temperature regulating plate 52, whereby the cooling is accelerated so that the surface thereof is smoothed to render the progress of the succeeding step smooth.

When the increase in temperature of the temperature regulating plate 52 is not detected any longer by the temperature detector, the table 11 of the laminate placing unit 10 is driven by the motor 12 and moved downward, whereby the coagulating layer SL is separated from the temperature regulating plate 52. At this time, since the release film 54 has its central portion fixedly mounted so that it is somewhat suspended, the release film 54 is gradually peeled from the side end of the coagulating layer SL, whereby the release film 54 can be easily separated without damaging the coagulating layer SL. From the foregoing, the hardening layer HL is formed, and after the coagulating layer SL has been separated from the release film 54, the table 11 of the laminate placing unit 10 stops at a position lowered downward by a thickness portion of the coagulating layer SL formed to wait for the slot forming step to be performed next.

The above-described various devices are each controlled by the control device 70 to obtain a three-dimensional model as desired. The section vector data are sequentially transmitted from the graphic work station 200 to the control device 70, and control commands are transmitted to various devices constituting the molding apparatus 300 on the basis of the data.

The forming step, the releaser coating step, the coagulating agent coating step, and the coagulating agent coagulating step shown in Fig. 3(a) to Fig. 3-(e) are repeated, whereby the hardening layers HL are sequentially laminated to complete a laminate structure LS having a desired shape. The completed laminate structure LS is physically divided along the releaser R printed at a suitable location to thereby obtain the coagulating agent S having a desired shape covered with the releaser R. The releaser R for covering the coagulating agent S is weak in bonding force so that it can be easily removed from the coagulating agent S. Further, if the releaser R is washed with a diluent, the bonding force of the releaser R can be further weakened, and the laminate structure LS having a desired shape can be more easily obtained.

In the following, the laminate molding method using the three-dimensional model molding system MS in the second embodiment will be described with reference to Figs. 4(a) to 4(e), which are sectional views showing the steps of the laminate molding method using the three-dimensional model molding system MS in the second embodiment. First, the slot forming step shown in Fig. 4(a) is executed on the basis of the section vector data transmitted. In the present embodiment, a rotary cutter is used as a slot cutting machine 60', which is provided with a cutting tooth 62' rotatably driven by a motor 61' and a dust cleaner 63' for attracting dust cut off by the cutting tooth 62'. This rotary cutter is driven by a motor, not shown, and moved in directions of X and Y on the basis of the command from the control device 70, and a sectional contour of a three-dimensional model is formed by a slot groove SG.

First, the cutter is guided by the X-rail 18 to a forming position of a slot groove SG1 formed this time and moved to cut and form the slot groove SG in a vertical direction by the cutting tooth 62', and after this, the cutting tooth 62' is rotated to the forming position of a slot groove SG2 formed next time to cut the latter, and the cutter is moved in the direction of X while moving upward. By doing this, a draft angle is formed so that the separation characteristic when the laminate is separated can be enhanced. The cut dust generated at that time is attracted and removed by the dust cleaner 63'. Further, since it is a mechanical cutter, even in the case where inflammable materials are used for the coagulating agent S and the releaser R, an ignition preventing device is not necessary, and there is a merit that the range of selection for materials is enlarged.

Subsequently, the releaser printing step for printing the releaser R on the slot groove SG formed is carried out as shown in Fig. 4(b). This

step is carried out using the ink jet type printer used in the first embodiment. A photo-hardening resin is used as the releaser R. If the photo-hardening resin is used, there are merits that the hardening time is short and no vaporization of a solvent is present. However, the operation is similar to that of the first embodiment except that the photo-hardening resin which is the releaser R is printed along the draft angle, description of which is therefore omitted.

When the releaser R is printed on all the predetermined region SL3, the releaser R is hardened by the release hardening device 30 as shown in Fig. 4(c). Since the used releaser R is a photo-hardening resin, a lamp 31 for irradiating light having a specific wavelength is used in the releaser hardening device 30. In the case where the ultraviolet hardening resin is used as the photo-hardening resin, there can be used various ultraviolet generating light sources such as a so-called quartz low-voltage mercury lamp, a heavy hydrogen lamp, a bactericidal lamp, a photo-polymerization lamp, and a black light lamp. These light sources are cheaper than a ultraviolet laser, and a light source for generating light having a desired wavelength for hardening a photo-hardening resin can be selected. Further, in the case where a visible photo-hardening resin is used, since the resin is hardened by irradiating a visible light for several tens sec., a blue fluorescent lamp, a metal halide lamp, etc. can be used as a light source. Since these light sources can obtain larger energy as compared with a laser, it is possible to completely harden the photo-hardening resin in a shorter period of time.

When the releaser R is hardened, the coagulating agent coating step shown in Fig. 4(d) is carried out. In the present embodiment, a spray applicator is used for the coagulating agent coating device 40. The operation of the coagulating agent coating device 40 is similar to that of the coating device in the first embodiment, description of which is therefore omitted. In the coating device used in the first embodiment, since the coating head 44 is in contact with the hardening layer HL of the laminate structure LS previously formed, when the coating head 44 is moved, the hardening layer HL is sometimes dragged. However, in this spray applicator, the coagulating agent S is formed into mist from a spray nozzle 45 and the coagulating agent is sprinkled on the uppermost surface, whereby the coagulating agent S can be coated (sprinkled) without dragging the hardening layer HL of the laminate previously formed. Further, it is possible to form a uniform coagulating agent layer SL over the whole region of the uppermost surface.

Accordingly, as shown in Fig. 4(e), in the coagulating agent coagulating step, a cooling fan 55 for merely cooling the coagulating agent S can be used as the coagulating agent layer coagulating device 50. This cooling fan 55 is guided along the Y-rail 16 by a motor, not shown, while rotating a fan 57 whose rotary speed is controlled according to a temperature of the coagulating agent layer SLL to cool and coagulate the coagulating agent layer SLL. The cooling fan 55 is very simple in construction, and so, the installation cost can be suppressed.

In the case of this embodiment, slurry-like ceramics may be used as a releaser, and metal flame-sprayed from the metal flame-sprayer may be used as a coagulating agent. The thickness of a metal layer may be 30 µm to 0.2 mm. The thickness of a releaser layer of slurry-like ceramics may be 20 µm to 0.1 mm or so. If so, when spraying, metal can be coagulated mechanically at a low temperature, and an internal stress resulting from contraction when coagulated less occurs to reduce generation of strain. Metal grains are sprayed by the metal flame-sprayer to form a coagulating layer, after which a solid shape of the surface is measured by a three-dimensional measuring unit, not shown, and sent to the graphic work station 200 for use with the adapt ion control for determining a section for producing section vector data to be transmitted after next time. If so, there leads to the merit that the precision of the model shape as desired is good even if the precision of the thickness of the coagulating layer to be produced by the spray is poor.

In the following, the laminate molding method using the three-dimensional model molding system MS in a third embodiment will be described with reference to Figs. 5(a) to 5(d), which are sectional views showing the steps of the laminate molding method using the three-dimensional model molding system MS in the second embodiment. Since the three-dimensional model molding system MS in the present embodiment uses a sheet-like solid coagulating agent S cut into a predetermined size in advance, this is provided with a sheet carrying device 80, a release sheet holding device 90, a sheet compression and melting device 100, and a coagulating agent layer cooling device 110 in place of the provision of the coagulating agent coating device 40, the coagulating agent layer coagulating device 50, and the releaser hardening device 30. For the releaser printing device 20, an electrostatic transfer type printer is used.

The releaser printing device 20 is provided at an inlet of the three-dimensional model molding system MS, and the electrostatic transfer type printer is used. The electrostatic transfer type printer is provided with an electrostatic drum 23 and a transfer sheet 25. The electrostatic drum 23 is charged in adjustment with an output data pattern,

to which adheres to a toner, and after this, the toner is transferred to the transfer sheet 25 to print it on a printing object. In the present embodiment, there is provided a construction in which in replace of a toner, a releaser R adheres to the electrostatic drum 23. Since the detailed construction and function of the electrostatic transfer type printer is known, description thereof is omitted.

The sheet carrying device 80 is the device in which a coagulating sheet SS positioned at the uppermost layer of the coagulating agent sheets SS laminated is carried to the uppermost surface of a hardening layer HL having the releaser R printed thereon. This device is provided with a carrying mechanism 81 for holding the coagulating agent sheet SS to carry it to a predetermined position.

The sheet compression and melting device 100 is the device in which the coagulating agent sheet SS placed on the uppermost surface of the hardening layer HL by the sheet carrying device 80 is molten to form a coagulating agent layer SLL covering the releaser R to integrate it with the uppermost surface. This device is constituted of a heating plate 101 housing a heater therein, which is fixedly installed.

The release sheet holding device 90 is the device for holding and moving a release sheet 91 between a sheet compression and melting device 100, described later, and a coagulating agent layer cooling device 110. This device holds the release sheet 91 for preventing the coagulating agent sheet SS from adhering to the heating plate 101 of the sheet compression and melting device 100 even if the coagulating agent sheet SS is molten by being positioned on the upper surface of the coagulating agent sheet SS.

The coagulating agent layer cooling device 110 is the device for cooling the coagulating agent layer SLL to form the hardening layer HL. This device is composed of a temperature sensor, not shown, a temperature controller, and a cooling plate 111 housing a refrigerant pipe therein, which are fixedly installed.

The steps of the laminate molding method will be described hereinafter while explaining the function of these devices.

First, the slot forming step starts for forming the slot groove SG on the hardening layer HL previously formed on the basis of the section vector data, as shown in Fig. 5(a). This step is the same as the slot forming step in the first embodiment, description of which is therefore omitted.

Subsequently, the predetermined region SL3 of the coagulating layer formed in the slot forming step is subjected to the releaser printing step for printing the releaser R as shown in Fig. 5(b). The electrostatic drum 23 is charged on the basis of command from the controller 70 so that a printing pattern is formed from the slot groove SG1 previously formed to the slot groove SG2 formed next time, and the releaser R adheres thereto. The releaser R formed on the printing pattern is transferred to the transfer sheet 25, and the releaser R appears on the printing surface by movement of the transfer sheet 25. The table 11 of the laminate placing unit operatively connected to the transfer sheet 25 is moved in the direction of Y to thereby print the releaser R on the uppermost surface.

The releaser used herein comprises a toner for the electrostatic transfer type printer which has a melting point of 140 °C and comprises a resin powder whose main component is polyester. If various colors of the toner are used, colored releaser printing can be easily carried out. In addition thereto, on the grain surface having a high heat resistance such as graphite fluoride, ceramic, silicone, etc. can be used powder applied with coating for adjusting the charging property of polyester or the like.

Even after the releaser R has been printed, the table 11 of the laminate placing unit moves and stops at a position at which the sheet compression and melting device 100 is fixedly mounted to execute the coagulating agent layer forming step as shown in Fig. 5(c). When the table 11 of the laminate placing unit stops, the coagulating agent sheet SS is carried to the hardening layer HL having the releaser R printed thereon by the sheet carrying device 80, and the release sheet 91 is positioned on the coagulating agent sheet SS by the release sheet holding device 90. When the coagulating agent sheet SS is carried by the sheet carrying device 80 and the release sheet 91 assumes a predetermined position by way of the release sheet holding device 90, the table 11 of the laminate placing unit moves upward where the coagulating agent sheet SS is pressed against the heating plate 101 heated by the internal heater. Then, the coagulating agent sheet SS begins to melt to form the coagulating agent layer SLL in a molten state so as to embrace the printed releaser R.

The coagulating agent sheet SS used herein is preferably one made of a material having a melting point lower than that of the releaser R, such as a polyethylene sheet having a melting point of approximately 110 °C, and having a large wet-angle with respect to the releaser R.

After a lapse of a predetermined time, the table 11 of the laminate placing unit moves downward, moves in the direction of X and stops at a position where the coagulating agent layer cooling device 110 is fixedly mounted to execute the hardening layer forming step as shown in Fig. 5(d). At this time, the release sheet holding device 90 operatively connected to the table 11 of the laminate

placing unit also moves in the direction of Y. The table 11 of the laminate placing unit starts its upward movement when the former stops its movement in the direction of Y, the coagulating agent layer SLL is pressed against the cooling plate 111. The cooling plate 111 is controlled in temperature by a temperature sensor, a temperature control portion and the housed refrigerant pipe so that when the temperature of the coagulating agent layer SLL is high, the temperature of the cooling plate 111 is controlled to be lower, and as the coagulating agent layer SLL is cooled, the temperature of the cooling plate 111 is controlled to a predetermined value, thereby forming the hardening layer HL at a predetermined temperature.

When the hardening layer is thus formed, the table 11 of the laminate placing unit again starts its downward movement. At this time, since the release sheet 91 is placed and held on the coagulating agent layer SLL, the smooth hardening layer HL can be obtained without damaging the hardening layer HL.

In the case of this embodiment, as the coagulating agent sheet SS, there may be used one in which a coagulating agent is applied to paper, which is a fibrous sheet. The thickness of paper is 50 µm to 0.2 mm, and the thickness of the coagulating agent is about 20 to 50 µm. Although paper coated with the coagulating agent is not shown, it may be passed through a heat roller or the like in advance to melt the coagulating agent on the coated paper, in which state the paper is carried to and placed on the hardening layer HL having the releaser R printed, after which the cooling plate 111 is pressed to coagulate the coagulating agent to form a new hardening layer HL.
By doing so, it is possible to save trouble that the coagulating agent sheet SS is placed on the hardening layer HL having the releaser R printed thereon, after which it is heated and molten using the heating plate 101. Accordingly, this results in the advantage that the productive efficiency of the three-dimensional model is enhanced and the productivity is improved.

Further, unless the releaser R printed on the hardening layer HL is solidified, when the coagulating agent sheet SS is placed thereon, the releaser R is sometimes spread laterally between the coagulating agent sheet SS and the hardening layer HL.
In the case where one with a coagulating agent applied to the paper is used, the releaser R may permeate to the coated paper since the paper itself is fibrous, but is not spread laterally. Accordingly, in the step in which the slot groove SG is formed in the hardening layer HL, on the basis of the section vector data with the three-dimensional model being fed, to form a contour, the contour having the smallest dimension is finished. In this case, even if the releaser R printed on the hardening layer HL is not solidified, one in which a coagulating agent is applied to the coated paper is heated and molten in advance and superposed (placed). Therefore, the shaping (molding) speed of the three-dimensional model can be increased to further improve the productivity.

Furthermore, there is a great economical advantage that the coated paper cheaper than the 100% coagulating agent sheet SS is provided as the constituent element of the laminate shaped article whereby the shaped article can be marketed at less cost.

In the following, the laminate molding method using the three-dimensional model molding system MS in a fourth embodiment will be described with reference to Figs. 6(a) to 6(d), which are sectional views showing the steps of the laminate molding method using the three-dimensional model molding system MS in the fourth embodiment. The laminate molding method using the three-dimensional model molding system MS in the present embodiment uses a roll sheet-like coagulating agent sheet SS, while the laminate molding method using the three-dimensional model molding system MS in the third embodiment used the coagulating agent sheet SS, to enhance the continuity of the steps, there being provided with a sheet supply device 80' in place of the sheet carrying device 80, and a sheet cut-out device 120 for cutting out a necessary portion of the roll sheet-like coagulating sheet SS. Further, an electrostatic transfer type printer for directly printing the releaser R on the roll sheet-like coagulating agent sheet SS used is not provided with a transfer sheet.

The sheet supply device 80' is composed of a supply roll 82' for supplying the roll sheet-like coagulating agent sheet SS, and a winding roll 81' for winding the roll sheet-like coagulating agent sheet SS from which the necessary portion is cut out, there being controlled so that the roll sheet-like coagulating agent sheet SS is moved in synchronism with the electrostatic drum 23 of the electrostatic transfer type printer.

The sheet cut-out device 120 is composed of a cutter 121 for cutting out the roll sheet-like coagulating agent sheet SS placed on the laminate structure LS into a predetermined size, a motor (not shown) for moving the cutter in a vertical direction, and a guide rail 122.

The steps of the laminate molding method will be described hereinafter while explaining the function of these devices.

First, the slot forming step for forming a slot groove SG starts, as shown in Fig. 6(a), for the hardening layer HL previously formed on the basis of the section vector data. This step is the same as

the slot forming step in the first embodiment, description of which is therefore omitted.

Subsequently, the formed predetermined region SL3 is subjected to the releaser printing step for printing the releaser R as shown in Fig. 6(b). The electrostatic drum 23 is charged on the basis of command from the controller 70 so that a printing pattern is formed from the slot groove SG1 previously formed to the slot groove SG2 formed next time, and the releaser R adheres thereto. The releaser R formed on the printing pattern is directly transferred to and printed on the roll sheet-like coagulating agent sheet SS, and a next surface to be printed appears by movement of the roll sheet-like coagulating agent sheet SS.

The roll sheet-like coagulating agent sheet SS having the releaser R printed thereon stops its movement when the former arrives at a predetermined position, and when the table 11 of the laminate placing unit moves upward and placed on the laminate structure LS, the cutter 121 of the sheet cut-out device 120 is driven by a motor, not shown, the cutter 121 moving downward while being guided by the guide 122 to cut out the coagulating agent sheet SS into a predetermined size, after which the cutter 121 moves upward. When the coagulating agent sheet SS is cut out into a predetermined size as described above, the table 11 of the laminate placing unit starts its movement in the direction of Y and stops at a position where the sheet compression and melting device 100 is fixedly mounted to effect the coagulating agent layer forming step as shown in Fig. 6(c).

When the table 11 of the laminate placing unit stops, the release sheet 91 is positioned on the coagulating agent sheet SS cut out into a predetermined shape by the release sheet holding device 90, and when the release sheet 91 is positioned at a predetermined position, the table 11 of the laminate placing unit moves upward to press the coagulating agent sheet SS against the heating plate 101 heated by the internal heater. Then, the coagulating agent sheet SS begins to be molten to form the coagulating agent layer SLL so as to embrace the printed releaser R.

After a lapse of a predetermined time, the table 11 of the laminate placing unit moves downward, moves in the direction of X and stops at a position where the coagulating agent layer cooling device is fixedly mounted to execute the hardening layer forming step as shown in Fig. 6(d). At this time, the release sheet holding device 90 operatively connected to the table 11 of the laminate placing unit also moves in the direction of Y. The table 11 of the laminate placing unit starts its upward movement when the former stops its movement in the direction of Y, the coagulating agent layer SLL is pressed against the cooling plate 111. The cooling plate 111 is controlled in temperature by a temperature sensor, a temperature control portion and the housed refrigerant pipe so that when the temperature of the coagulating agent layer SLL is high, the temperature of the cooling plate 111 is controlled to be lower, and as the coagulating agent layer SLL is cooled, the temperature of the cooling plate 111 is controlled to a predetermined value, thereby forming the hardening layer HL at a predetermined temperature.

When the hardening layer HL is thus formed, the table 11 of the laminate placing unit again starts its downward movement. At this time, since the release sheet 91 is placed and held on the coagulating agent layer SLL, the smooth hardening layer HL can be obtained without damaging the hardening layer HL.

In the case where slurry-like ceramics is used as a releaser and metal flame-sprayed from the metal flame-sprayer is used as a coagulating agent, after a desired shape has been obtained, pressure of about 100 tons at approximately 1000 °C is applied for about 40 hours by a hot press, not shown, to effect a diffusion bonding. After gradual cooling, the ceramics is divided into sections into a predetermined shape, which may be taken out. By doing so, a metal model which is high in shear stress and high in accuracy in dimension can be fabricated. This leads to an advantage that the model can be used as a mold.

Also in this case, as the coagulating agent sheet SS, one in which a coagulating agent is applied to paper which is a fibrous sheet may be used, as previously mentioned. When one in which a coagulating agent is applied to paper is delivered from the supply roll 82', it is allowed to pass through a heat roller or the like in advance to melt the coagulating agent on the coated paper, in which state, it is carried onto the hardening layer HL having the releaser R printed thereon. It is then cut out into a predetermined shape on the basis of section vector data of the three-dimensional model by the sheet cut-out device 120, and the cut-out is placed on the hardening layer HL of the laminate structure LS. Thereafter, the cooling plate 111 may be pressed to coagulate the coagulating agent to form a new hardening layer HL.

As described in detail in the foregoing, in the three-dimensional model molding system MS and the laminate molding method using the three-dimensional model molding system MS in the present embodiment, there is provided the releaser printing device 20 for applying (printing) the releaser R by way of printing, and therefore, the releaser R can be printed on only the region to be printed (applied).

Further, by printing (applying) the releaser R on only the desired region, it is not necessary to

form a large recess in the hardening layer HL as in prior art but the linear slot groove SG may be formed, thus facilitating the output adjustment of a carbon dioxide gas laser and improving the working efficiency.

Furthermore, in the third and fourth embodiments, since the solid sheet-like agent is used as the coagulating agent, there are advantages that a device for keeping the coagulating agent S in a molten state is not necessary, and the coagulating agent S is easily handled.

While the present invention has been described by way of the several embodiments, it is to be noted that the present invention is not limited to the above-described embodiments but various modifications and improvements may be made without departing from the spirit and the scope of the present invention.

For example, while in the present embodiments, the temperature regulating plate is used as the coagulating agent layer coagulating device, it is sufficient that the coagulating agent layer may be coagulated and a predetermined thickness may be obtained. For example, if a temperature regulating roller is used, it is not necessary that the laminate placing unit need not be operated up and down to enable the simplification of the construction of the molding apparatus.

Moreover, while in the present embodiments, the carbon dioxide gas laser type slot cutting machine and the rotary cutter are used as the slot cutting machine, it is to be noted that a mechanical cutter may be used, and if the mechanical cutter is used, the depth accuracy of the slot groove formed can be improved and the width of the slot groove can be narrowed.

INDUSTRIAL APPLICABILITY

As will be apparent from the above explanation, in the laminate molding method and apparatus, since the printing means and printing device are used as means for applying a releaser, it is possible to apply the releaser to only the necessary portion. Further, since the releaser can be printed on only the necessary portion, it is sufficient that a narrow slot groove may be formed, and the output control of the laser irradiation light can be facilitated and the working efficiency can be improved. Furthermore, since a coating area of the releaser is small, it is possible to obtain a laminate model without a residual releaser and having a high molding accuracy.

Claims

1. A laminate molding method for laminating hardening layers composed of a coagulating agent and a releaser to thereby obtain a laminate having a desired shape, said method comprising:

   a first step of forming a slot groove in a coagulating layer constituting a surface of the laminated hardening layer to divide the coagulating layer into a necessary region constituting the laminate having a desired shape and an unnecessary region not constituting the laminate having a desired shape;

   a second step of printing a releaser on a predetermined region of a coagulating layer constituting the surface of the hardening layer or a predetermined region of a coagulating agent sheet constituting a new coagulating layer;

   a third step of forming a new non-coagulated state coagulating agent layer on the coagulating layer with the releaser printed thereon or on the hardening layer; and

   a fourth step of coagulating the coagulating agent layer to form a new hardening layer.

2. The laminate molding method according to claim 1, wherein in said third step, a non-coagulated coagulating agent is applied to the surface of the coagulating layer having the releaser printed thereon to a predetermined thickness to form a coagulating agent layer in a non-coagulated state.

3. The laminate molding method according to claim 1 or 2, wherein in said third step, the coagulating agent comprises a coagulating agent in which polyvinyl alcohol and a co-compound are added to urea.

4. The laminate molding method according to claims 1 to 3, wherein in said second step, the releaser comprises a photo-hardening resin material.

5. The laminate molding method according to claim 1, wherein in said third step, a coagulating agent sheet is placed on the coagulating layer having the releaser printed thereon, and the coagulating agent sheet is molten to thereby form a coagulating agent layer in a non-coagulated state.

6. The laminate molding method according to claim 1, wherein in said third step, a coagulating agent sheet having the releaser printed thereon is cut out into a predetermined size, and the cut-out coagulating agent sheet is molten to form a coagulating agent layer in a non-coagulated state.

7. The laminate molding method according to claims 1 to 6, wherein in said second step, the releaser is printed on the coagulating layer corresponding to a region of the exclusive logic sum of a necessary region, an unnecessary region and a slot groove formed in upper and lower hardening layers.

8. The laminate molding method according to claims 1 to 7, wherein in said fourth step, the coagulating layer in a non-coagulated state is pressed against a temperature regulating plate through a film having a high releasing property.

9. The laminate molding method according to claims 1 to 8, wherein in said first step, a laser beam is irradiated to form a slot.

10. The laminate molding method according to claims 1 to 9, wherein in said first step, the slot is formed at a predetermined angle of inclination in a vertical plane with respect to a slot forming direction.

11. The laminate molding method according to claims 1 to 10, wherein in said second step, plural colors of releasers are used so that a desired color is generated in a desired region.

12. A laminate molding apparatus for laminating hardening layers composed of a coagulating agent and a releaser to thereby shape a laminate having a desired shape, said apparatus comprising:

slot forming means for forming a slot groove in a coagulating layer constituting a surface of the laminated hardening layer to divide the coagulating layer into a necessary region constituting the laminate having a desired shape and an unnecessary region not constituting the laminate having a desired shape;

releaser print means for printing the releaser on a predetermined region of the coagulating layer constituting the surface of the hardening layer or a predetermined region of a coagulating agent sheet constituting a new coagulating layer;

coagulating agent layer forming means for forming a new non-coagulated state coagulating agent layer on the coagulating layer on which the releaser is printed or on the hardening layer; and

coagulating agent layer coagulating means for coagulating the coagulating agent layer to form a new hardening layer.

13. The laminate molding apparatus according to claim 12, wherein in said coagulating agent layer forming means, a non-coagulated coagulating agent is applied in a predetermined thickness to the surface of the laminate on which the plurality of hardening layers are laminated and formed to form the coagulating agent layer in a non-coagulated state.

14. The laminate molding apparatus according to claim 12, wherein said coagulating agent layer forming means comprises a spray applicator for spraying a non-coagulated coagulating agent applied in a predetermined thickness to the surface of the laminate on which the plurality of hardening layers are laminated and formed.

15. The laminate molding apparatus according to claim 12, wherein said coagulating agent layer forming means comprises coagulating agent sheet place means for placing the coagulating agent sheet on the coagulating layer having the releaser printed thereon, and coagulating agent layer melting means for melting the coagulating agent sheet to thereby form the coagulating agent layer in a non-coagulated state.

16. The laminate molding apparatus according to claim 12, wherein said coagulating agent layer forming means comprises coagulating agent sheet place means for placing the coagulating agent sheet having the releaser printed thereon on the hardening layer; coagulating agent sheet cut-out means for cutting out the coagulating agent sheet into a predetermined size; and coagulating agent layer melting means for melting the coagulating agent sheet to thereby form the coagulating agent layer in a non-coagulated state.

17. The laminate molding apparatus according to claims 12 to 16, wherein said slot forming means comprises a laser beam irradiation machine.

18. The laminate molding apparatus according to claims 12 to 16, wherein said slot forming means comprises a mechanical cutter.

19. The laminate molding apparatus according to claims 12 to 18, wherein said releaser printing means comprises an ink jet type printer.

20. The laminate molding apparatus according to claims 12 to 18, wherein said releaser printing means comprises an electrostatic transfer type

printer.

FIG. 1

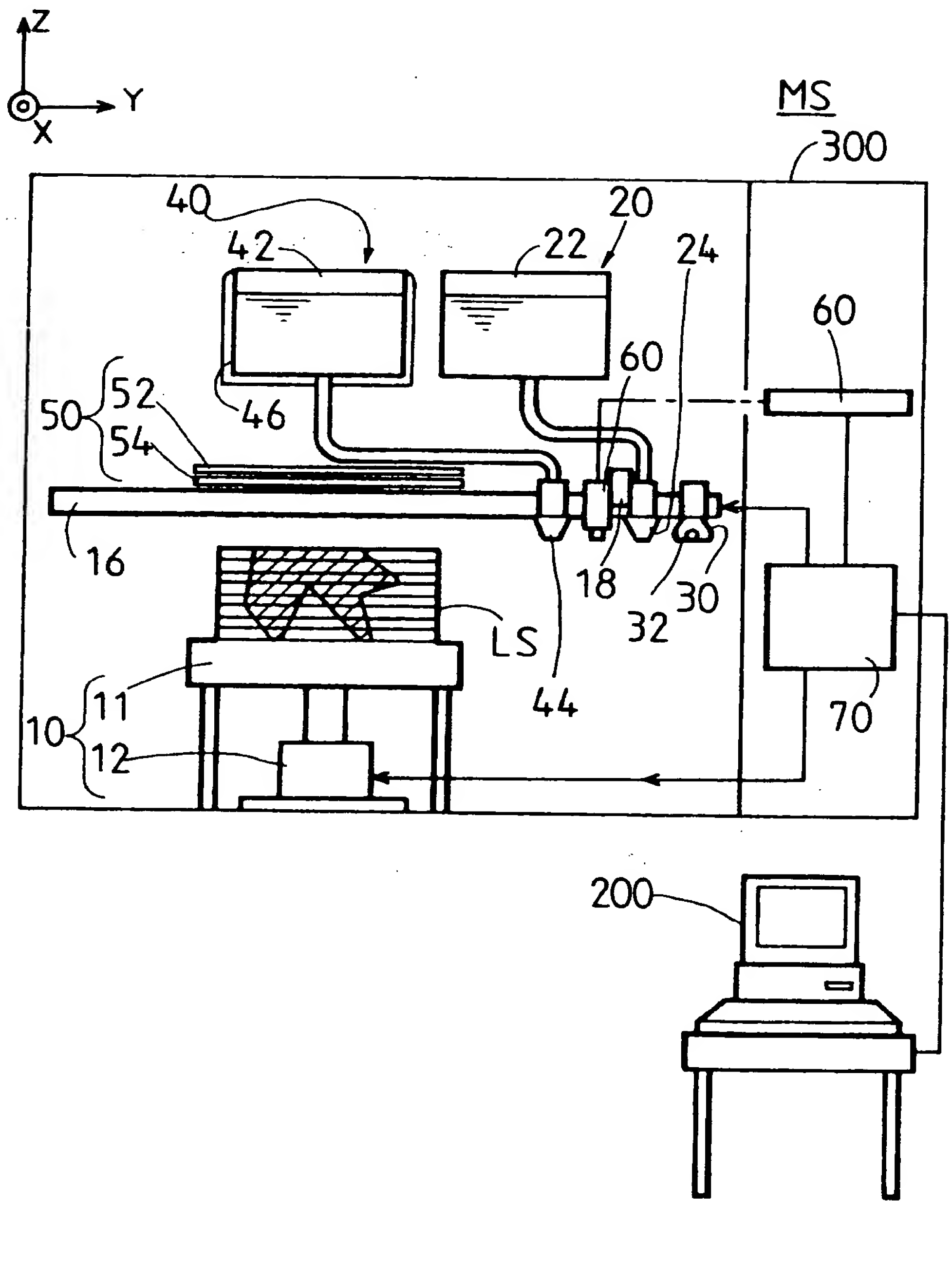

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FIG. 2

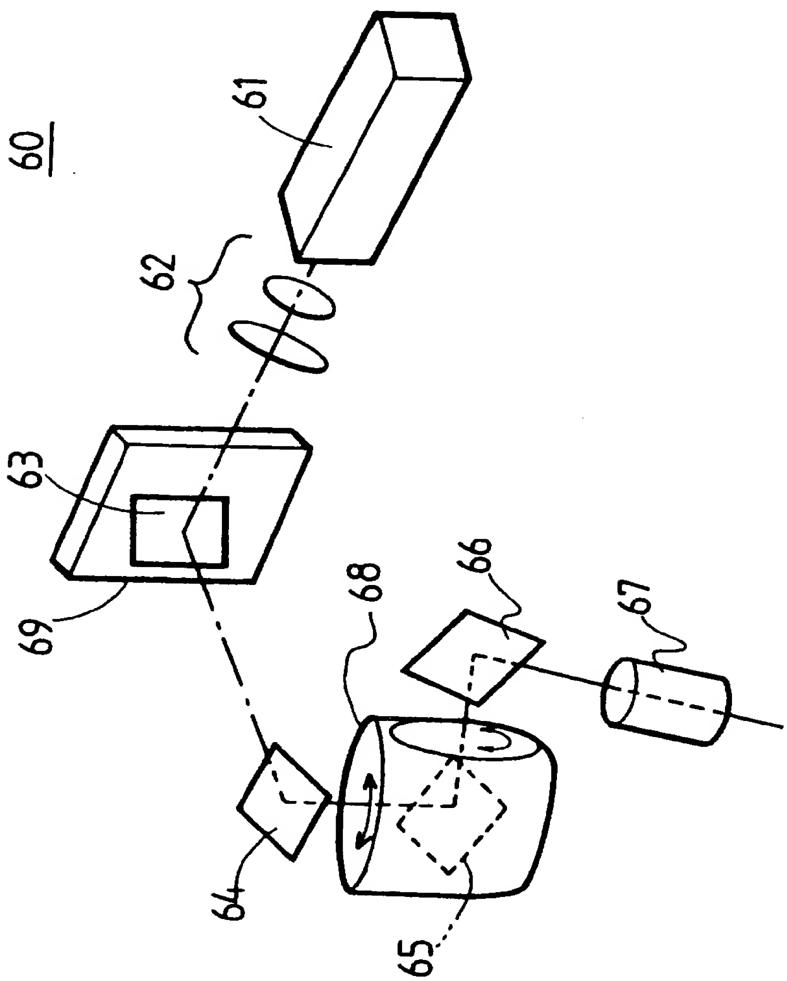

FIG. 3

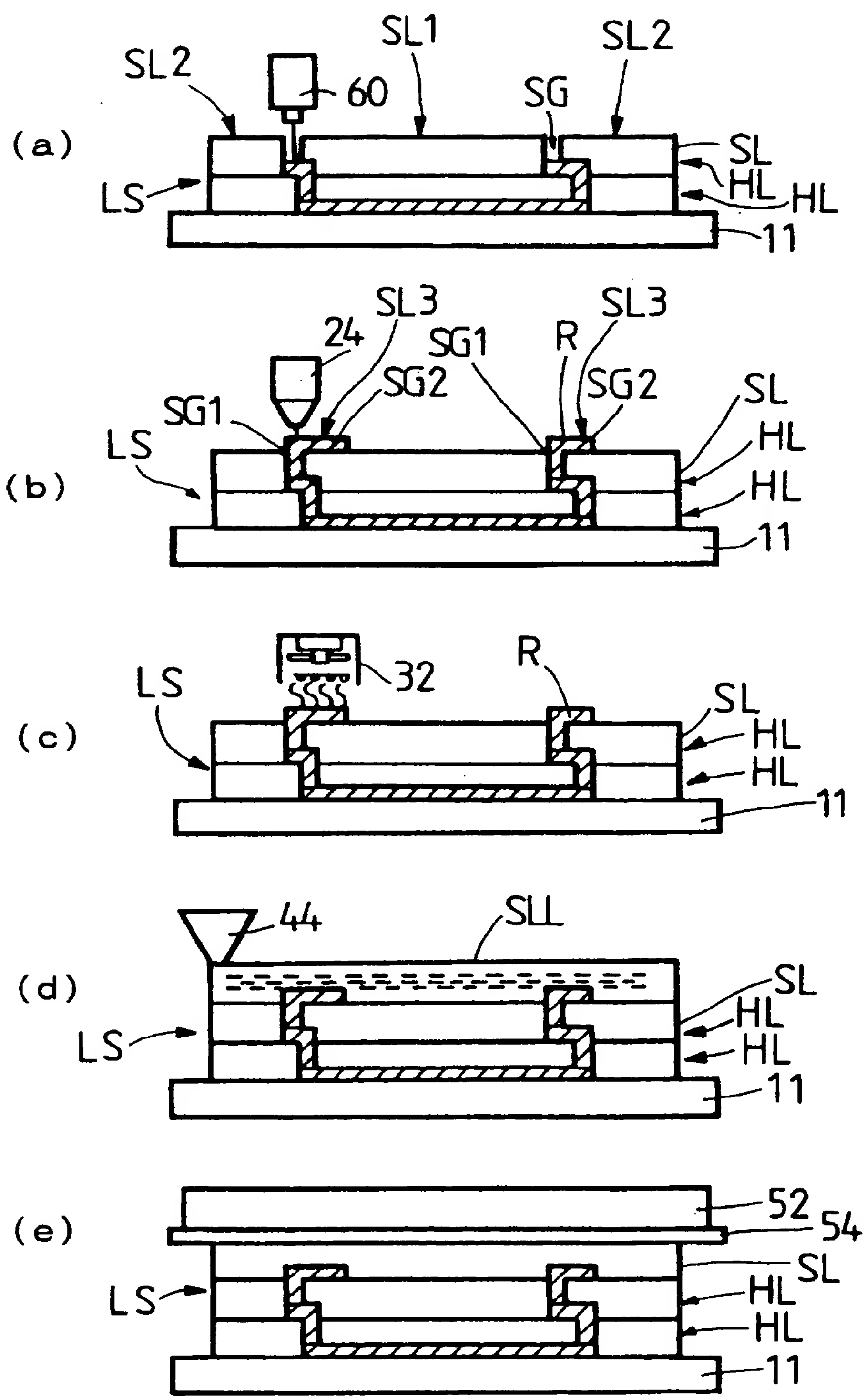
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FIG. 4

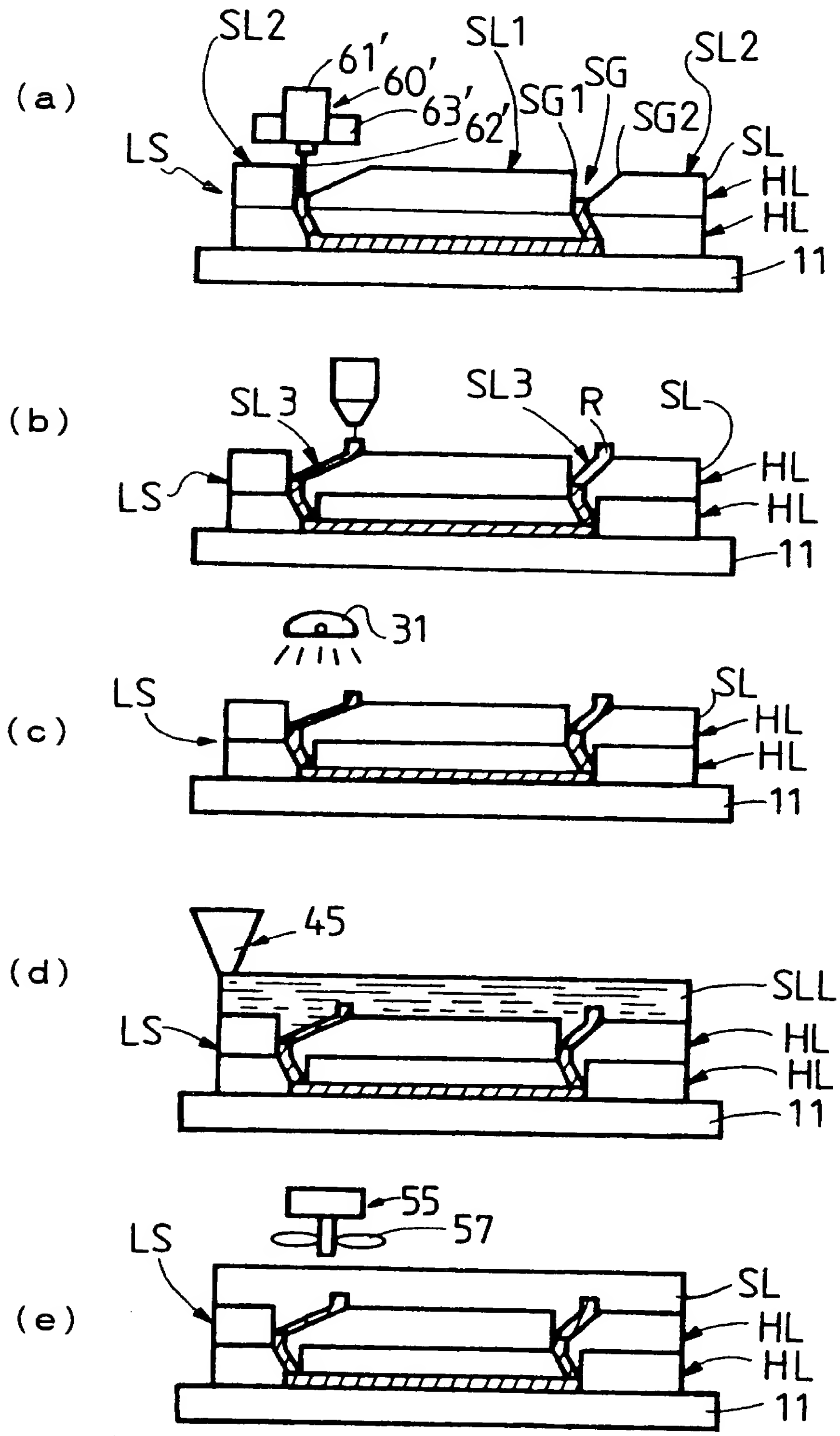
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FIG. 5

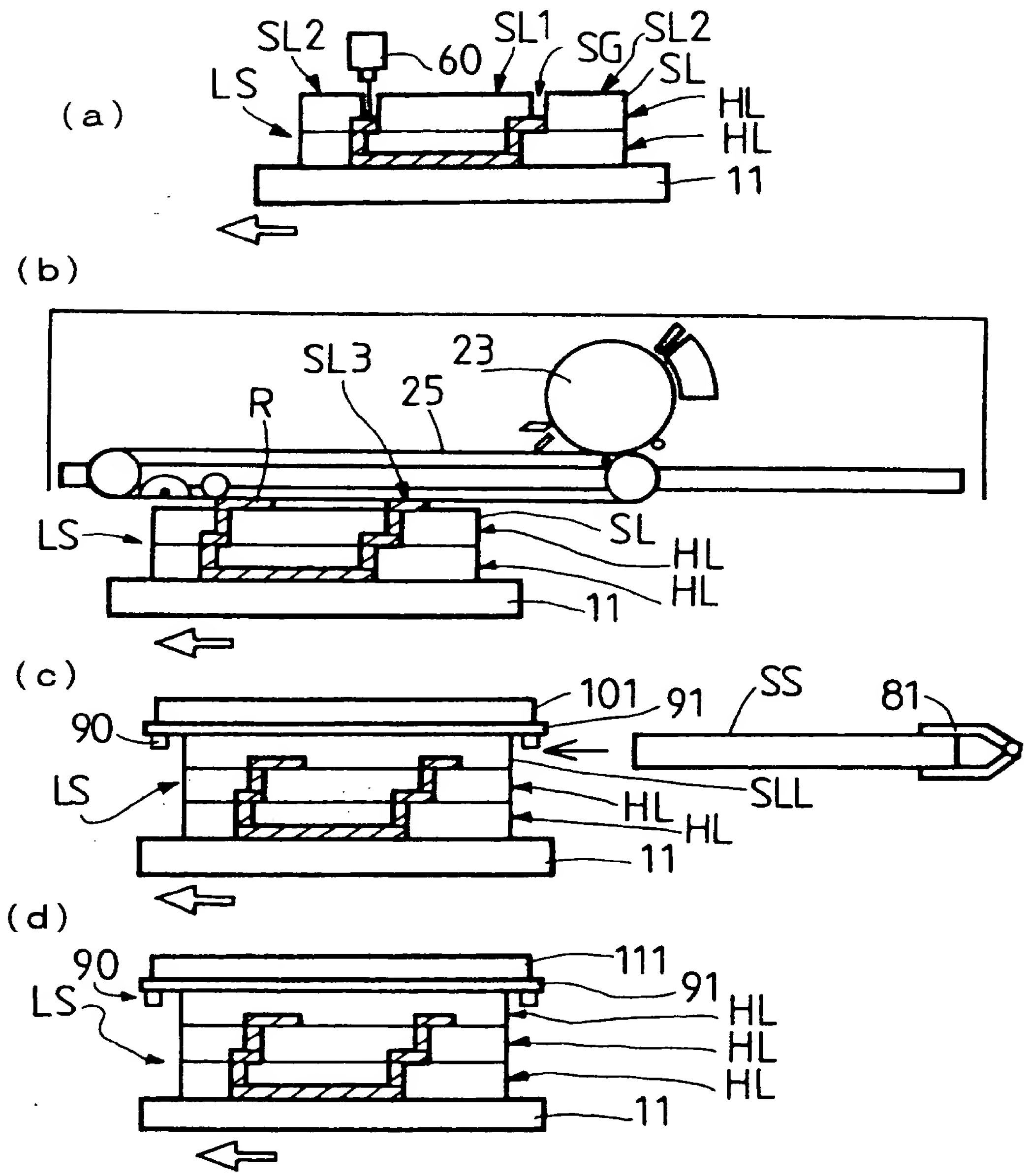
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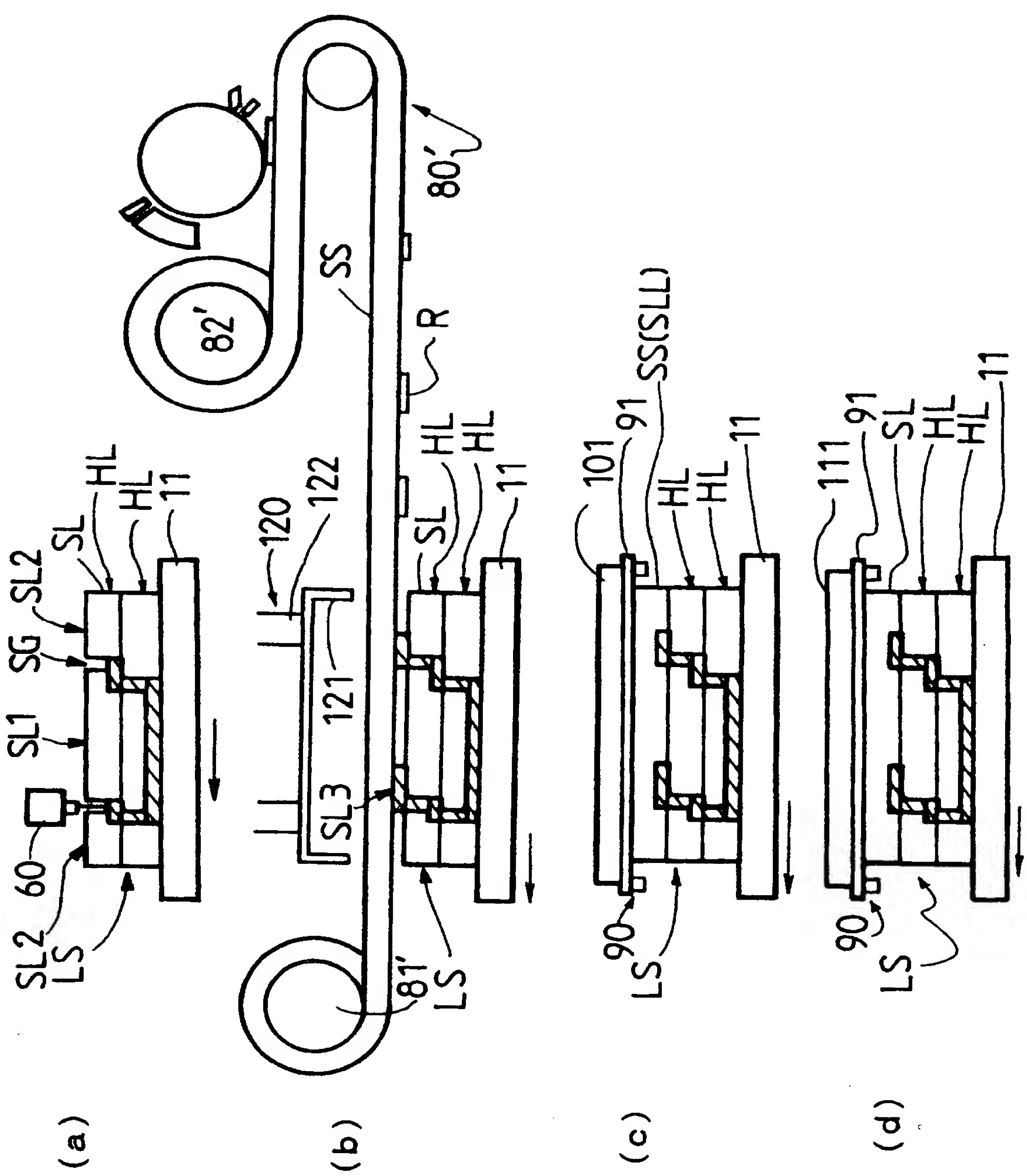
FIG. 6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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP94/02205

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl6 B29C67/06, B29C35/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl6 B29C67/06, B29C35/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1955 - 1994
Kokai Jitsuyo Shinan Koho	1971 - 1994

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, A, 3-158228 (Storatacis, Inc.), July 8, 1991 (08. 07. 91), Claim, line 2, lower right column, page 5 to line 5, lower left column, page 15, Figs. 1 to 12 (Faimly: none)	1-20
A	JP, A, 4-62037 (Mitsubishi Heavy Industries, Ltd.), February 27, 1992 (27. 02. 92), Claim, line 9, upper right column, page 2 to line 6, upper left column, page 3, Fig. 1 (Family: none)	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search March 2, 1995 (02. 03. 95)	Date of mailing of the international search report March 20, 1995 (20. 03. 95)
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